Exercise Two is suggested as an introductory exercise.

■ ★ 1.0 hours

Introduction to Photogeologic Mapping

Instructor Notes

Suggested Correlation of Topics

Geologic time, geometric relations, geomorphology, maps, remote sensing, satellite observations, stratigraphy

Purpose

The objective of this exercise is to demonstrate how observations of a planet can be used to produce geologic maps. This includes the identification of rock units and placement of units in a time sequence.

Materials

Suggested: clear acetate or overhead transparency, overhead projector markers, tape

Substitutions: tracing paper and pencil

Background

Planetary photogeologic mapping differs from geologic mapping on Earth because field work generally is not possible. Photogeologic mapping depends on photo interpretation, supplemented with other remote sensing data. Despite the lack of "ground truth," photogeologic maps are important for deriving the geologic histories of planetary surfaces. It is assumed that students are familiar with geologic processes and landforms, as investigated in earlier exercises.

All additional information for completing this exercise is contained in the student's introduction. Student maps can be overlaid for comparison. Variation will occur based on the characteristics chosen to delineate each unit. Have the students discuss with each other the reasoning behind their unit selection.

Science Standards

- Physical Science
  - Motions and forces
- Earth and Space Science
  - Origin and evolution of the Earth system

Answer Key

1. Answers will vary. At a minimum students should list the following: Terrain One: dark plains—smooth (low relief), dark (low albedo), sparsely cratered, topographically low areas; Terrain Two: bright highlands—rough (high relief), light (high albedo), heavily cratered, topographically high areas. Possible additional terrains include: large young craters with rayed ejecta and moderate albedo highlands.

2. Answers will vary given terrains selected. For the terrains listed in question 1, the highlands are the oldest, the smooth plains are younger, and rayed craters are the youngest. Students should see that the rayed craters are superposed (on top) of the other terrains, and that the smooth plains cover (embay) the highlands.

Unit Descriptions

Unit Name	Observation	Interpretation
Smooth Plains	Smooth plains, few craters (mostly small), low albedo	Volcanic flow
Highlands	Rugged, numerous craters are various sizes, high albedo, topographically high	Old, heavily modified surface, possibly of volcanic origin

3. The graben is younger than the unit that contains it (the highlands).

4. The smooth plains are younger than the highlands. The highlands contain more craters, larger craters, and more eroded craters. In addition, the graben ends at the contact. It is overlain by the volcanic smooth plains.

5. The ridge is younger.

6. The crater is younger.

Stratigraphic Column

	Geologic Unit	Structural Features
Youngest		Crater on Ridge Ridge
	Smooth Plains	
		Graben
Oldest	Highlands	

Geologic History: This region was initially covered by a unit, possibly of volcanic origin, which was heavily cratered and modified by continued cratering. After formation of the highlands, tectonism occurred, as evidenced by the graben. Volcanic flows were emplaced in map area, represented by the smooth plains unit. No source area for the flows is identifiable within the mapped area. Cratering continued after the emplacement of the smooth plains unit. There has been a continuation (or reactivation) of tectonic activity in this area, indicated by the ridge. Finally, cratering has continued—represented by the crater on the ridge.

Name ____________________

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Purpose

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Materials

Clear acetate or overhead transparency, overhead projector markers, tape (or tracing paper and pencil)

Introduction

More than three decades of planetary exploration show that the surfaces of the solid planets and satellites have been subjected to the same geologic processes: **volcanism, tectonism** (e.g., earthquakes), **gradation** (erosion, etc.), and **impact cratering.** The relative importance of each process differs from planet to planet, depending upon the local environment. For example, a planet not having running water, such as the Moon, will experience erosion of a different style and intensity in contrast to a planet having abundant running water such as Earth.

Prior to the space program, the importance of impact cratering as a geologic process was not fully appreciated. It is now known that all of the planets were subjected to intense impact cratering in the early history of the solar system. Indeed, most of the craters on the Moon are of impact origin. On some planets, such as the Moon and Mercury, evidence of the impact process is preserved; on other planets, such as Earth, impact cratering is less evident. On the Moon, craters range in size from tiny micro craters of sub-millimeter size to the giant impact basins such as the 1300 km-diameter Imbrium basin.

A geologic map is a graphic portrayal of the distribution and sequence of rock types, structural features such as folds and faults, and other geologic information. Such a map allows geologists to represent observations in a form that can be understood by others and links the observations made at different localities into a unified form. In many respects, a geologic map is like a graph to a physicist; it allows one to understand many observations in a comprehensive form.

The **unit** is the basic component of geologic maps. By definition, it is a three-dimensional body of rock of essentially uniform composition formed during some specified interval of time and that is large enough to be shown on a conventional map. Thus, the making of geologic maps involves subdividing surface and near-surface rocks into different units according to their type and age. On Earth, geologic mapping involves a combination of field work, laboratory studies, and analyses of aerial photographs. In planetary geology, geologic mapping is done primarily by remote sensing methods--commonly interpretation of photographs. Field work is rather costly and not always possible. Mapping units are identified on photographs from **morphology** (the shape of the landforms), **albedo** characteristics (the range of “tone” from light to dark), color, state of surface preservation (degree of erosion), and other properties. Remote sensing of chemical compositions permits refinements of photogeologic units. Once units are identified, interpretations of how the unit was formed are made. In planetary geologic mapping the observation and interpretation parts of a unit description are separated (see figure 15.1).

After identifying the units and interpreting their mode of formation, the next task in preparing a photogeologic map is to determine the stratigraphic (age) relation among all the units. Stratigraphic relations are determined using: (a) the **Principle of Superposition,** (b) the law of cross-cutting relations, (c) embayment, and (d) impact crater distributions. The Principle of Superposition states that rock units are laid down one on top of the other, with the oldest (first formed) on the bottom and the youngest on the top. The law of cross-cutting relations states that for a rock unit to be modified (impacted, faulted, eroded, etc.) it must first exist as a unit. In other words, for a rock unit that is faulted, the rock is older than the faulting event. Embayment states that a unit "flooding into" (embaying) another unit must be younger. On planetary surfaces, impact crater frequency is also used in determining stratigraphic relations. In general, older units show more craters, larger craters, and more degraded (eroded) craters than younger units.

Once the stratigraphic relations have been determined, the units are listed on the map in order from oldest (at the bottom) to youngest (at the top). This is called the **stratigraphic column.** The final task, and the primary objective in preparing the photogeologic map, is to derive a general geologic history of the region being mapped. The geologic history synthesizes, in written format, the events that formed the surface seen in the photo -- including interpretation of the processes in the formation of rock units and events that have modified the units -- and is presented in chronological order from oldest to youngest.

Figure 15.1 shows a sample geologic map, including its unit descriptions and stratigraphic column. The relative ages were determined in the following manner: The cratered terrain has more (and larger) craters than the smooth plains unit -- indicating that the cratered terrain unit is older. In addition, fault 1 cuts across the cratered terrain, but does not continue across the smooth plains. Faulting occurred after the formation of the cratered terrain and prior to the formation of the smooth plains -- indicating that the smooth plains unit is younger than the cratered terrain and fault 1. The crater and its ejecta unit occurs on top of the smooth plains unit, and thus is younger. Finally, fault 2 cuts across all the units, including the crater and its ejecta unit, and is thus the youngest event in the region. The geologic history that could be derived from this map would be similar to the following:

"This region was cratered and then faulted by tectonic activity. After the tectonic activity, a plains unit was emplaced. Cratering continued after the emplacement of the smooth plains unit, as seen by the craters superposed on the smooth plains and the large, young crater mapped as its own unit. Finally, there has been a continuation (or reactivation) of tectonic activity, indicated by the major fault which postdates the young crater. "

Questions

The Near Side of the Moon

Examine Figure 15.2, an observatory photograph of the near side of the Moon and answer the following questions:

1. Visually separate the different areas of the Moon into terrains (for example, continents and oceans on Earth). List the characteristics of each terrain.

2. Which terrain do you think is the oldest? the youngest? Explain why.

This figure shows that the surface of the Moon is not the same everywhere. The terrains, however, are not units in the strictest sense. Rather, each terrain is made up of many different units; close inspection of Figure 15.2 shows small areas having distinctive characteristics and that, when observed on high resolution photographs or on the ground, are seen to be distinct rock units.

Examine Figure 15.3. This photo shows in greater detail the boundary between two of the terrains you identified previously. Tape a piece of acetate or tracing paper over the photo. Mark the four corners as reference points in case the sheet shifts while you are working on it and also to allow for overlaying with other maps for comparison. Draw the contact between the rough highlands and the smooth plains. Note the feature indicated by the A on the photo. This is a graben caused by tectonic activity. The feature marked B on the photo is a ridge caused by tectonic activity. Trace these features on your map. Fill in the unit descriptions in the space provided below. Label the units on your map.

Unit Name	Observation	Interpretation

3. What is the age relation between the graben and the highlands? (Is the graben older or younger than the highlands?)

4. What is the age relation between the highlands and the smooth plains? What observations did you use to decide?

5. What is the age relation between the ridge and the smooth plains?

6. What is the age relation between the ridge and the large crater on it?

Place the geologic units and structural features identified above in their correct sequence in the stratigraphic chart below. List the oldest at the bottom and the youngest at the top.

	Geologic Unit	Structural Features
Youngest		
Oldest		

Using your unit descriptions and stratigraphic chart, write a short geologic history for the area you have mapped.

Geologic History:

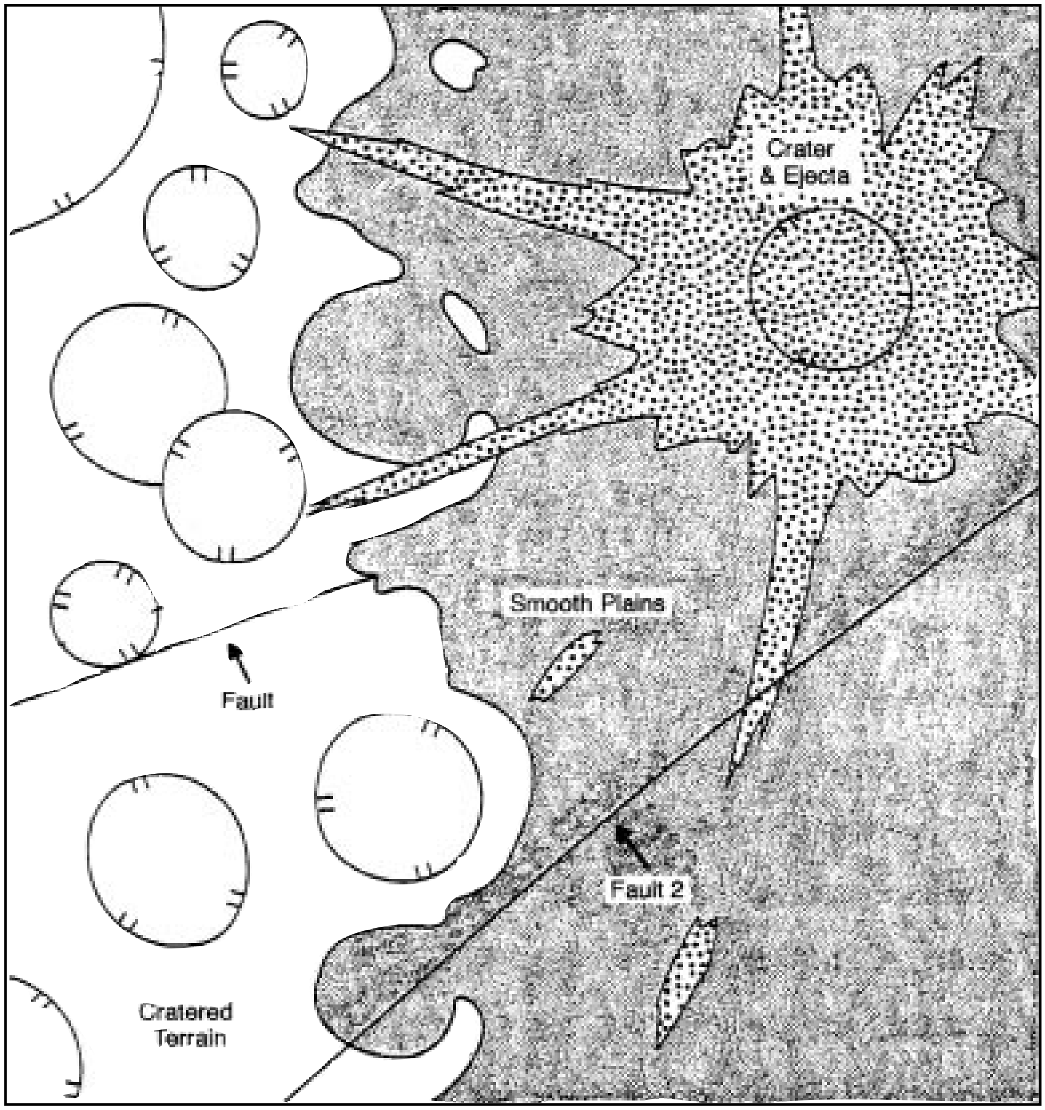

Figure 15.1. *Sample geologic map and derived stratigraphic column.*

Stratographic Column

	Geologic Unit	Structural Event
Youngest		Fault 2
	Crater and Ejecta	
	Smooth Plains	
		Fault 1
Oldest	Crater Terrain	

Unit Descriptions

Unit Name	Observation	Interpretation
Crater and Ejecta	rough, blocky surface, high albedo, surrounds and includes crater	crater and ejecta formed by impact
Smooth Plains	smooth plains, few craters, low albedo, lobate (rounded) margins	volcanic flow
Crater Terrain	rugged, heavily cratered plains, high albedo	old unit, possibly of volcanic origin, has had extensive cratering

Figure 15.2. *Near Side of the Moon. North is to the top. Photo courtesy of Ewen A. Whitaker, Unviersity of Arizona.*

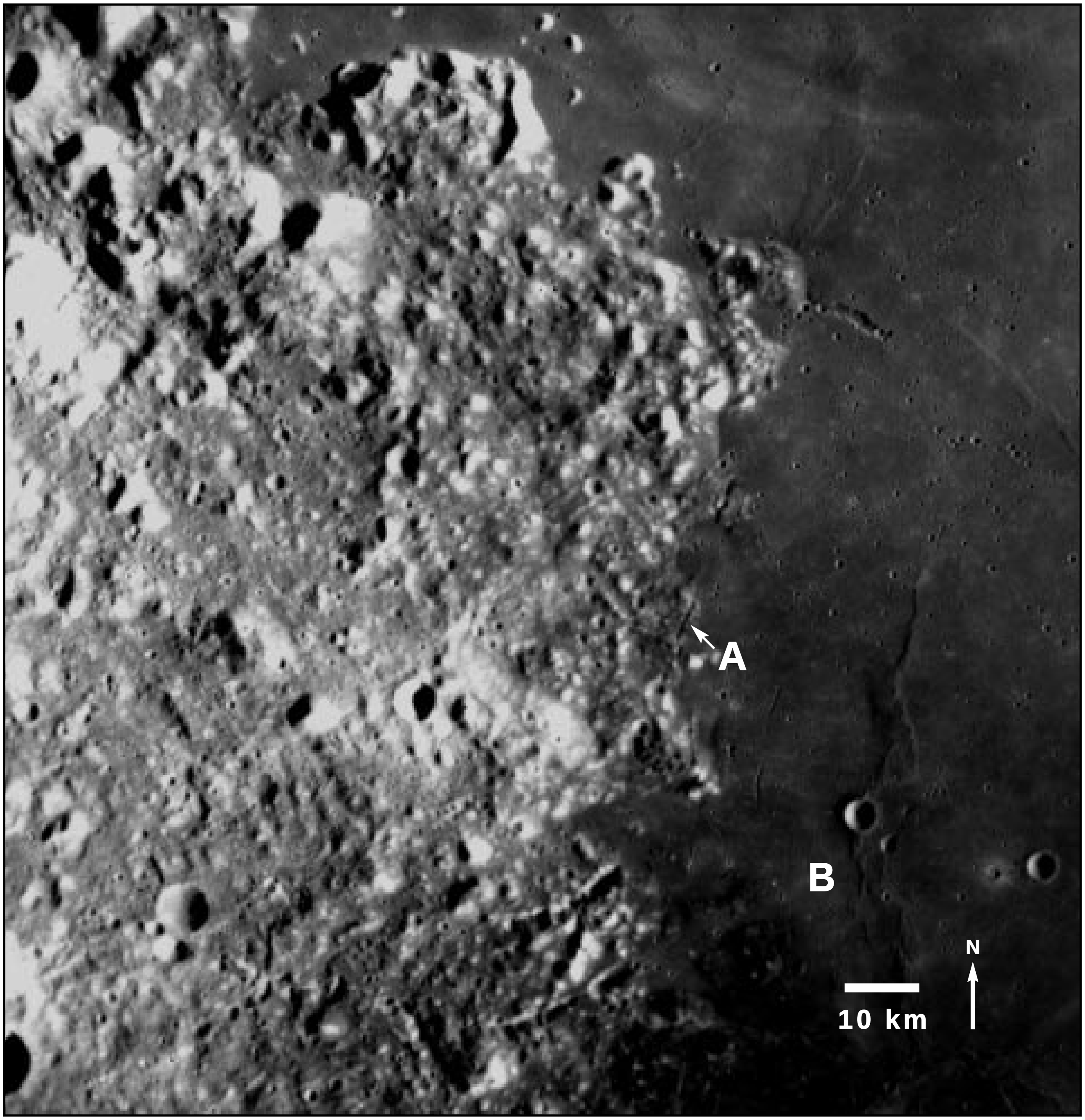

Figure 15.3. *Apollo 15 photograph of the moon. North is to the top. The small crater above the letter B is 3.8 kilometers in diameter. Apollo metric AS15 0583.*